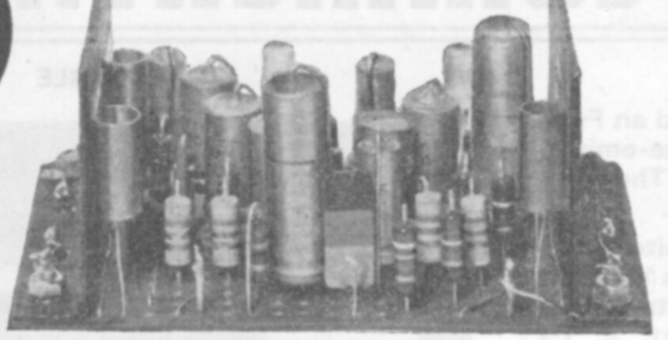

amplifier module

R. LEYLAND

THIS mains-powered a.f. amplifier is constructed on a small Veroboard panel measuring approximately 2½ × 3½in. At each end, a heat sink gives protection to the components and also serves as a support during soldering. Components are mounted upright to occupy the minimum area, and hole spacing on the Veroboard accommodates capacitor lead spacing satisfactorily. Flat mounting of components would secure them more firmly, but a board of larger area would be required.

An output on speech and music approaching 3 watts is obtained in a high flux 15Ω loudspeaker. When a continuous sine wave test signal is applied, more current is drawn from the supply and there is an appreciable drop in voltage. This restricts the output available under test conditions to about 2 watts. A loudspeaker of less than 15Ω impedance should not be connected as the currents in the output transistors to provide the increased power output would be excessive and would cause overheating and damage to these transistors.

Circuit Description

Included on the circuit board, in addition to the power amplifier, is a two-stage preamplifier with provision for connecting a treble control. The coupling capacitor, C6, between the pre-amplifier and power amplifier allows separation of the d.c. conditions in the two circuits. It is arranged that the collector voltage of Tr2 is at a lower voltage than at the base of Tr3, so ensuring the necessary polarizing voltage for the electrolytic capacitor, C6.

The mid-point voltage at the output is closely maintained by Tr3, to a value set by the potential divider consisting of the resistors R9, R10, R11 and R4 in series across the 24-volt supply. Carbon film resistors of 5% tolerance are used throughout the amplifier, making pre-set adjustments unnecessary, except for the choosing of a suitable value for R17.

The d.c. feedback loop via R14 also stabilises the currents in Tr3 and Tr4. The current in Tr3 is determined by the base-emitter potential of Tr4 across

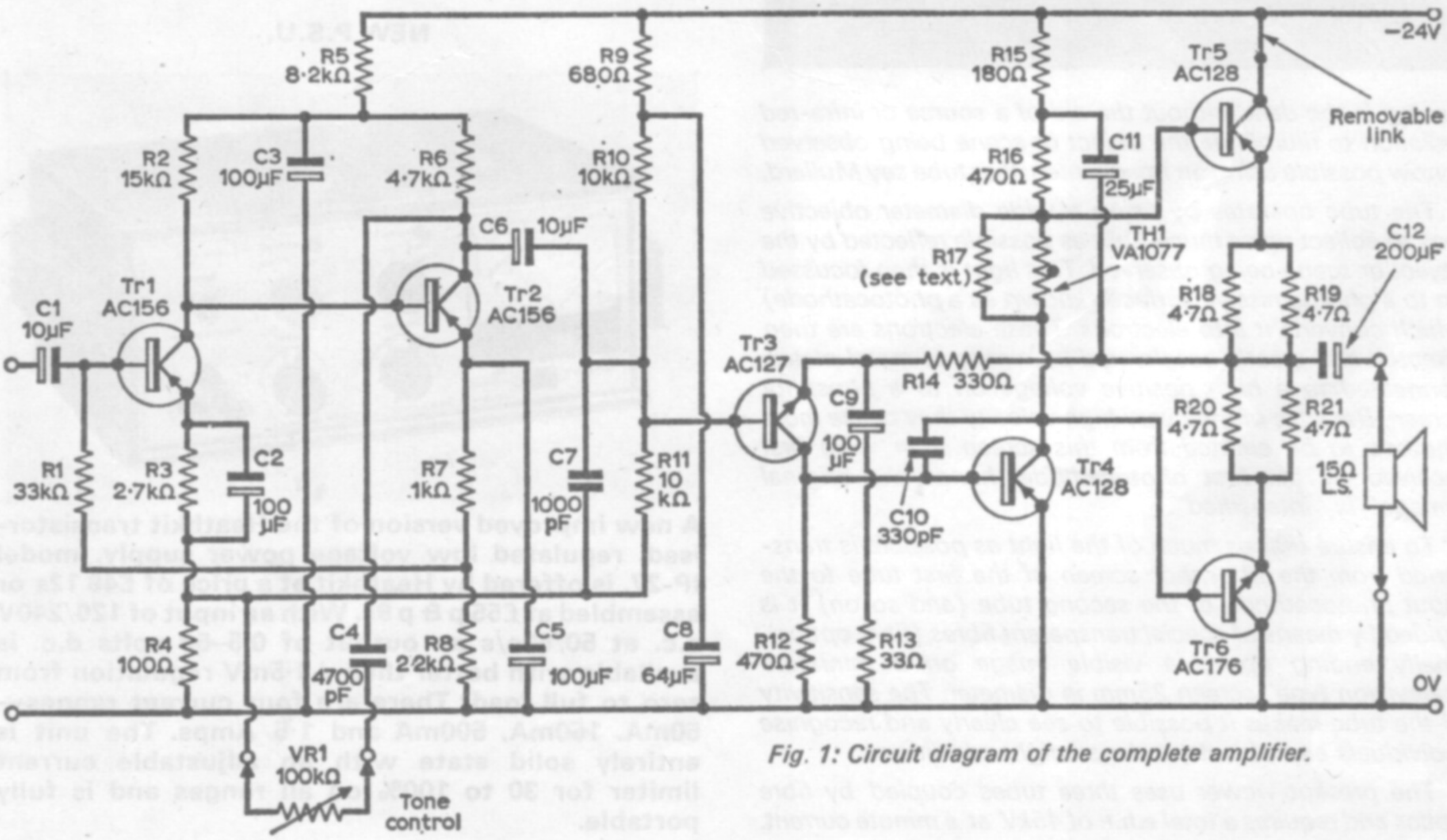

Fig. 1: Circuit diagram of the complete amplifier.

R12 and will be under 1mA. This current also flows in Tr5 and forms part of the quiescent current of this transistor. The current in the driver transistor, Tr4, is the amount required to drop half the supply voltage across the total resistance in the collector circuit. Because the driver transistor is a Class A stage, its quiescent current is much larger than the quiescent current in the Class B output stage.

Even with negative feedback, it is only possible to eradicate every trace of crossover distortion in the output stage by providing a small quiescent current of about 3mA. This is increased in Tr5 by an additional 1mA flowing from Tr3 to a total of about 4mA. The amount of this quiescent current is adjusted by changing the value of R17 as already described. Variation of the quiescent current with temperature is compensated by a Varite thermistor, type VA1077. This thermistor is rectangular in shape and measures 7·5 × 18 × 1·5 millimetres. It is colour-coded black, red, orange, and is the standard component for the circuit, which is on conventional lines in the driver and output stages.

The bootstrap capacitor, C11, applies the output voltage to the upper end of the driver load resistance R16, and providing the value is restricted to 25μF, permits a large drive voltage to be obtained with less inherent distortion.

Anything short of severe mismatching in the output stage will tend to be disguised by the action of the negative feedback. Nevertheless a matched complementary pair of transistors is necessary for optimum performance. These transistors, p-n-p type AC128 and n-p-n type AC176 must be put in their correct positions, otherwise the transistors will be damaged. Special care should be taken as the transistors look alike, and the markings can no longer be seen when the transistors are in the cooling clips.

Emitter resistors of 2·2Ω are required with the output transistors to improve thermal stability. Resistors of this value can be obtained, but the majority of suppliers only have values down to 4·7Ω. Two 4·7Ω resistors are therefore used in parallel at each emitter, giving a slightly higher effective value of 2·35Ω.

The driver transistor, Tr4, dissipates 240 milliwatts, and is mounted in a cooling clip on the same heat sink as Tr6. Preceding the driver transistor is an n-p-n transistor type AC127, and this should be enclosed in an insulating sleeve, since in this transistor, the collector is joined to the metal case.

The preamplifier, consisting of the transistors Tr1 and Tr2 increases sensitivity to about 8 millivolts r.m.s. for maximum output on a sine wave input signal. Decoupling of the two stages by R5 and C3 prevents undesirable feedback via the supply. Direct coupling between the preamplifier stages enables d.c. stabilising feedback to be applied over the two stages via R1. Negative signal feedback is applied through R11 to R4 in the emitter circuit of Tr1. The capacitor C3 reduces high-frequency distortion and noise. Additional frequency-dependent feedback can be applied by means of an external 100kΩ treble control. At maximum treble, the h.f. response extends to —3db at 15kc/s, and at minimum, it is about 14db down at 10kc/s.

The bass response extends to −30dB at 60c/s, some attention being provided by the low value of C12. If loudspeaker resonance occurs at about 60c/s, the bass response may be increased, but only slightly, because of the low output impedance. Capacitor C12 is kept outside the main feedback loop via R14, since low capacitance values in the feedback loop would tend to produce a peak in the low-frequency response. One advantage of the 200μF capacitor is that it takes up a minimum of space, and its working voltage need only be greater than half the supply voltage.

Construction

To improve heat transfer between the transistors and the cooling clips, silicone grease is applied before inserting the transistors. Burrs should be removed at holes when the cooling clips are to be fastened. As neither the heat sink nor the cooling clip are perfectly flat, it is best to smear some silicone grease on the cooling clips to fill any minute air gaps existing between them, air being a poor conductor of heat. The heat sinks are painted matt black except for the area occupied by the cooling clips, and a margin of 1/16in. around them. Electrical connection is made to the heat sinks on the flanges, and a small area around the securing bolts can be left unpainted for the purpose.

The leads of the output and driver transistors should be straightened to avoid contact with the heat sink or with each other. The mode in which

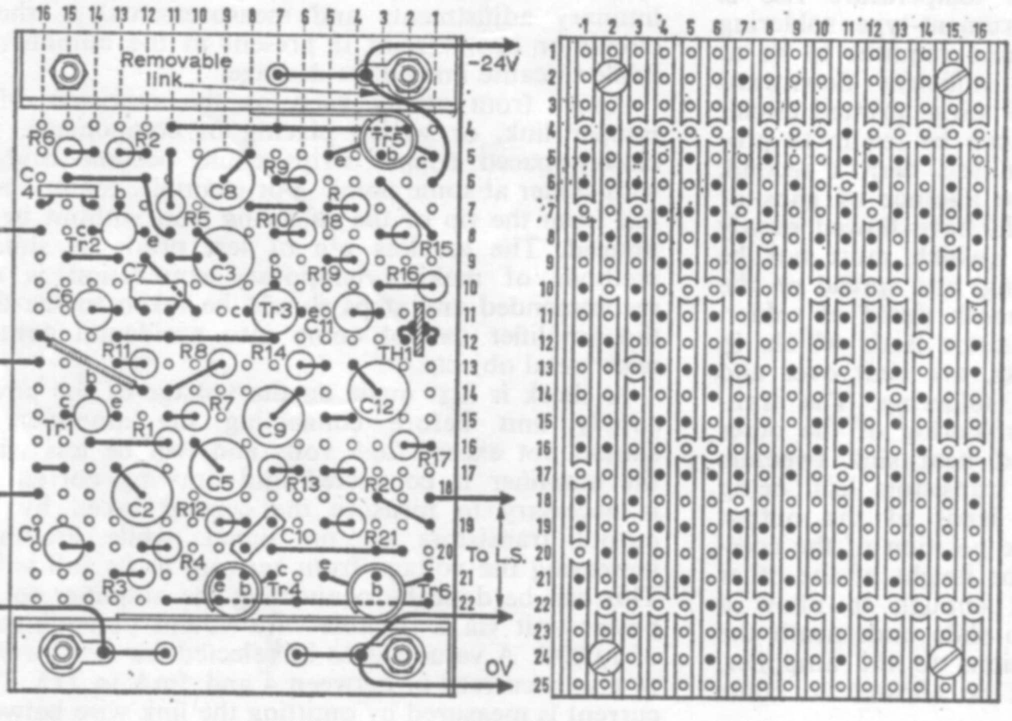

Fig. 2: Top view of the amplifier showing the positions of components. The diagram on the right shows the underside (copper side of Veroboard).

the transistors are inserted into the cooling clips is shown in the diagrams of Fig. 3.

At some positions on the Veroboard, two jumper links have to be inserted into the same hole. This is possible by using 24 s.w.g. tinned copper wire for the jumper links. When the hole has been located on the Veroboard, the wire is passed through from the copper side and back through the other hole where it is bent and held while the wire is drawn tight and pressed flat. The bent portions on the copper side are clipped with side cutters, leaving enough for soldering. If the bends are in opposite directions, the jumper link will stay in place until it is soldered. The jumper link adjacent to R11 should be insulated; similarly the lead of R12 adjacent to C10. All electrolytic capacitors should be fully insulated, either by a sleeve or if necessary by wrapping them with plastic tape before putting them into the circuit.

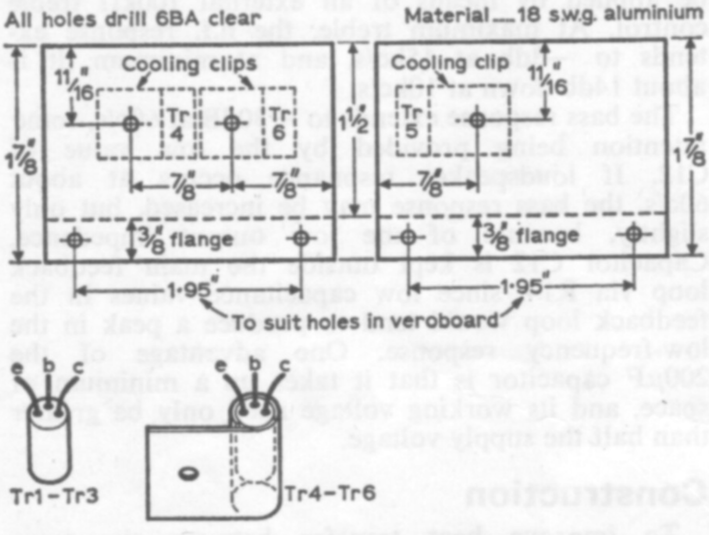

Fig. 3: Details of the heat sinks and transistor connections.

Efficient soldering depends upon the quick transference of heat, so that the temperature rise is localized. The tip of an instrument-type soldering iron is filed flat and tinned, and requires to be at the right temperature. With sufficient downward pressure on a flat joint, the 18 s.w.g. printed circuit solder melts immediately and can be fed in to produce a good soldered joint in less than a second. This can be recognised by the absence of gaps or irregularities. The solder should have flowed evenly all over the component lead (which must not be moved when the solder is setting) and spread on the metal to produce a bright smooth dome of solder. This method is ideal for transistor leads which, in common with the jumper links, are bent over and clipped to leave enough for soldering. The transistors are inserted after the soldering of the other components is completed, and heat sink tweezers are applied on the particular transistors lead being soldered. The length of the leads of the output transistors is determined by the position of the cooling clips on the heat sinks. The height of the other transistors can be made just enough to allow a cooling clip, held vertically, to slide underneath the transistor. In making connections to the amplifier, the soldering iron should not be allowed to come against any of the transistors.

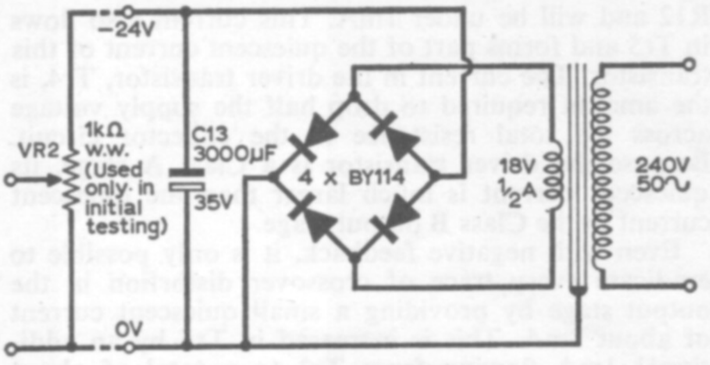

Fig. 4: Circuit of a suitable mains power supply.

The possibility of inserting components into the wrong positions, and later needing to remove them, encourages the use of another method for the resistors and capacitors, with their thicker leads. This is to keep the component leads straight, clip them to length, and hold the component in position until one lead is temporarily secured with solder. Solder is then run in around the leads. A clearance of about ⅛in. between components and the circuit board is usually advisable and allows the use of heat sink tweezers. It is not so quick and easy a method as the other one, and the soldering iron is only applied for a moment at a time, allowing the joint to cool before any further attempt is made.

Resistors are prepared for upright mounting by bending one lead over some form of 1/16in. diameter mandrel. Capacitors similarly have the negative lead brought down their sides, preferably inside the insulating sleeves. Components should be inserted as shown in Fig. 2.

Test Procedure

By following a cautious procedure in trying out the amplifier for the first time, it is possible to discover any mistake before damage is caused. There is only a narrow margin of safety with germanium output transistors, and small types are particularly susceptible to failure from thermal runaway. It is inadvisable to switch on without making some preliminary adjustments and measurements. A short-circuit or open-circuit if present in the amplifier is liable to cause immediate damage.

Apart from errors such as the omission of a jumper link, or wrong placing of components, the closely-spaced copper strips could become bridged with solder at some point. For example, solder could fall from the tip of the soldering iron without being noticed. The careless use of test prods or similar methods of making temporary connection is not recommended and steps should be taken to see that the amplifier cannot come into accidental contact with metal objects.

A check is first made on the voltage of the power supply unit before connecting the amplifier. It should not exceed 26·5 volts and will be less when the amplifier is connected and drawing current. It is necessary to measure the current taken by the output transistors on no signal, while gradually increasing the voltage from zero up to its full value. This can be done by connecting the amplifier to the power unit via a suitable wire-wound potentiometer of 1,000Ω. A value has to be selected for resistor R17 to give a current of between 4 and 5mA in Tr5. This current is measured by omitting the link wire between the terminal pin at the collector of Tr5 and the tag

—continued on page 407

A.F. AMPLIFIER MODULE

—continued from page 392

on the heat sink (Fig. 2) and connecting a millammeter in its place.

Beginning with a low value for R17, higher values are substituted ranging from 10 to 39Ω, until a current of between 4 and 5mA is obtained in Tr5 at full voltage, care being taken not to warm up the thermistor when soldering. To facilitate the selection of a resistor for R17, temporary lead wires can be soldered in place to which trial resistors can be attached by soldering, the voltage being reduced to zero to enable a new value of resistor to be substituted for R17 and then increased while measuring the collector current of Tr5, taking care that it does not reach an excessive amount.

The chief risk to guard against is an open circuit at R17, and the soldered joints at R17 must remain completely reliable, otherwise electrical failure will occur and replacement of the output transistors will become necessary. In each instance the joints should be tested mechanically before gradually turning up the supply voltage. The total current taken by the amplifier under quiescent conditions is about 27mA. ■

★ components list

Resistors:

R1	33kΩ	R12	470Ω
R2	15kΩ	R13	33Ω
R3	2·7kΩ	R14	330Ω
R4	100Ω	R15	180Ω
R5	8·2kΩ	R16	470Ω
R6	4·7kΩ	R17	See text
R7	1kΩ	R18	4·7Ω
R8	2·2kΩ	R19	4·7Ω
R9	680Ω	R20	4·7Ω
R10	10kΩ	R21	4·7Ω
R10	10kΩ		

All ½ watt 5% miniature

Capacitors:

C1	10μF 25V electrolytic
C2	100μF 16V electrolytic
C3	100μF 16V electrolytic
C4	4,700pF ceramic
C5	100μF 16V electrolytic
C6	10μF 25V electrolytic
C7	1000pF ceramic
C8	64μF 40V electrolytic
C9	100μF 16V electrolytic
C10	330pF ceramic
C11	25μF 25V electrolytic
C12	200μF 16V electrolytic

Transistors:

Tr1	AC156	Tr4	AC128
Tr2	AC156	Tr5	AC128
Tr3	AC127	Tr6	AC176

Miscellaneous:

Th1 Varite Thermistor type VA1077; Veroboard 2½ x 3¾in, 0·15in. pitch; 3 transistor cooling clips; 18 s.w.g. aluminium (see Fig. 4); VR1 100kΩ potentiometer